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FLIGHT TEST OF A HONEYWELL, INC., FLUIDIC YAW DAMPER

By

John C. Kidwell

July 1968

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-67-C-0057

BELL HELICOPTER COMPANY
FORT WORTH, TEXAS

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U. S. ARMY MATERIEL COMMAND

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DEPARTMENT OF THE ARMY
U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA 23604

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USAAVLABS Technical Report 68-53
July 1968

FLIGHT TEST OF A HONEYWELL, INC., FLUIDIC YAW DAMPER

Final Report

By

John C. Kidwell

Prepared by

Bell Helicopter Company
Fort Worth, Texas

for

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

SUMMARY

Flight tests were conducted to evaluate the performance and feasibility of a fluidic yaw damper system that was fabricated by Honeywell, Inc. A standard UH-1C helicopter was used as a test vehicle.

Tests encompassed 8.5 flight hours and 2.9 hours of ground and hangar tests. Operation of the system was normal at all times, and a significant increase in yaw damping was measured. None of the tests revealed any factors that might limit the application of fluidic systems in a helicopter environment. The performance and reliability of the "feasibility" package were much better than expected and helped to create a favorable impression of the concept. Pilot acceptance of the system was good, considering that only simple rate damping was provided without the benefit of pilot loops, quickening, and other sophisticated features of current electronic Stability and Control Augmentation Systems (SCAS). If fluidic stabilization systems were to be incorporated into a production helicopter, these additional features would have to be present to obtain pilot ratings equivalent to those generated by electronic SCAS.

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LIST OF SYMBOLS

BHC	Bell Helicopter Company
c.g.	Center of gravity, inches from datum
C.P.S.	Frequency, cycles per second
°C	Temperature, degrees Centigrade
°F	Temperature, degrees Fahrenheit
F/A	Fore and aft
G	Acceleration
Gain	Actuator travel per deg/sec of yaw rate, inches
IAS	Indicated airspeed, knots
KCAS	Calibrated airspeed, knots
psig	Pressure, pounds per square inch, gage
RPM	Rotational speed, revolutions per minute
V_{CAL}	Calibrated airspeed, knots
ζ	Damping ratio, fraction of critical

INTRODUCTION

Under the terms of Contract DAAJ02-67-C-0057, the Bell Helicopter Company conducted flight tests to evaluate the feasibility of a fluidic yaw damper system. The fluidic yaw damper system was designed and constructed by Honeywell, Inc., under the terms of Contract DAAJ02-67-C-0056. The tests were conducted on a UH-1C.

The objectives of the evaluation of the feasibility hardware damper package were:

1. To determine the magnitude of the installation and conversion procedure.

2. To obtain quantitative measures of the system's performance.

3. To obtain qualitative evaluations of the system by at least three pilots.

4. To recommend any necessary changes to the system to enhance its serviceability and performance.

The objectives of the evaluation were met during 15 flights which totaled 8.5 flight hours. The tests were conducted during the months of January and February 1968 at the Bell Helicopter Company, Flight Research Center, Fort Worth, Texas.

DISCUSSION

DESCRIPTION OF THE TEST HARDWARE

The test helicopter was a standard UH-1C, 64-14102, and was modified only in those areas required to accept the fluidic damper installation and the instrumentation. A detailed description of the test helicopter will not be presented here. Precise definition of the configuration is provided by Reference 3.

The fluidic yaw damper system that was tested provided a pressure signal output proportional to yaw rate. The required system performance was defined by USAAVLABS Technical Report 66-87, "Fluid State Hydraulic Damper," dated February 1967. Gain and response requirements for the damper system were taken from this report and are summarized in Figure 1.

The fluidic portion of the yaw damper is shown in Figure 2. This damper consists of a vortex rate sensor, two fluid amplifier stages, two capacitors (bellows), and an electrical trim valve. Transducers for measuring the performance of the various fluidic components are also integrated into this package.

The system, as packaged for installation in the test helicopter, is shown in Figure 3. The package included a self-contained low-pressure hydraulic power supply for the fluidic damper system. This hydraulic unit controlled system flow and temperature. A temperature-controlled bypass valve and a heat exchanger maintained fluid temperature at approximately 110°F. Flow was controlled by four valves connected in parallel with the fluidic control.

Details of the series servo actuator are provided in USAAVLABS Technical Report 66-87. This servo actuator, operating with a 1500-psi supply, provided a displacement proportional to the low-pressure hydraulic signals delivered by the fluidic control. This servo actuator was designed to prevent transfer of fluids between the low-pressure hydraulic system and the high-pressure aircraft system. The servo actuator authority in the directional control system was ±12.5 percent of the total control travel.

INSTALLATION AND CHECKOUT

The fluidic yaw damper system was received at the Bell Helicopter Company on 17 January 1968. Installation of the system began immediately.

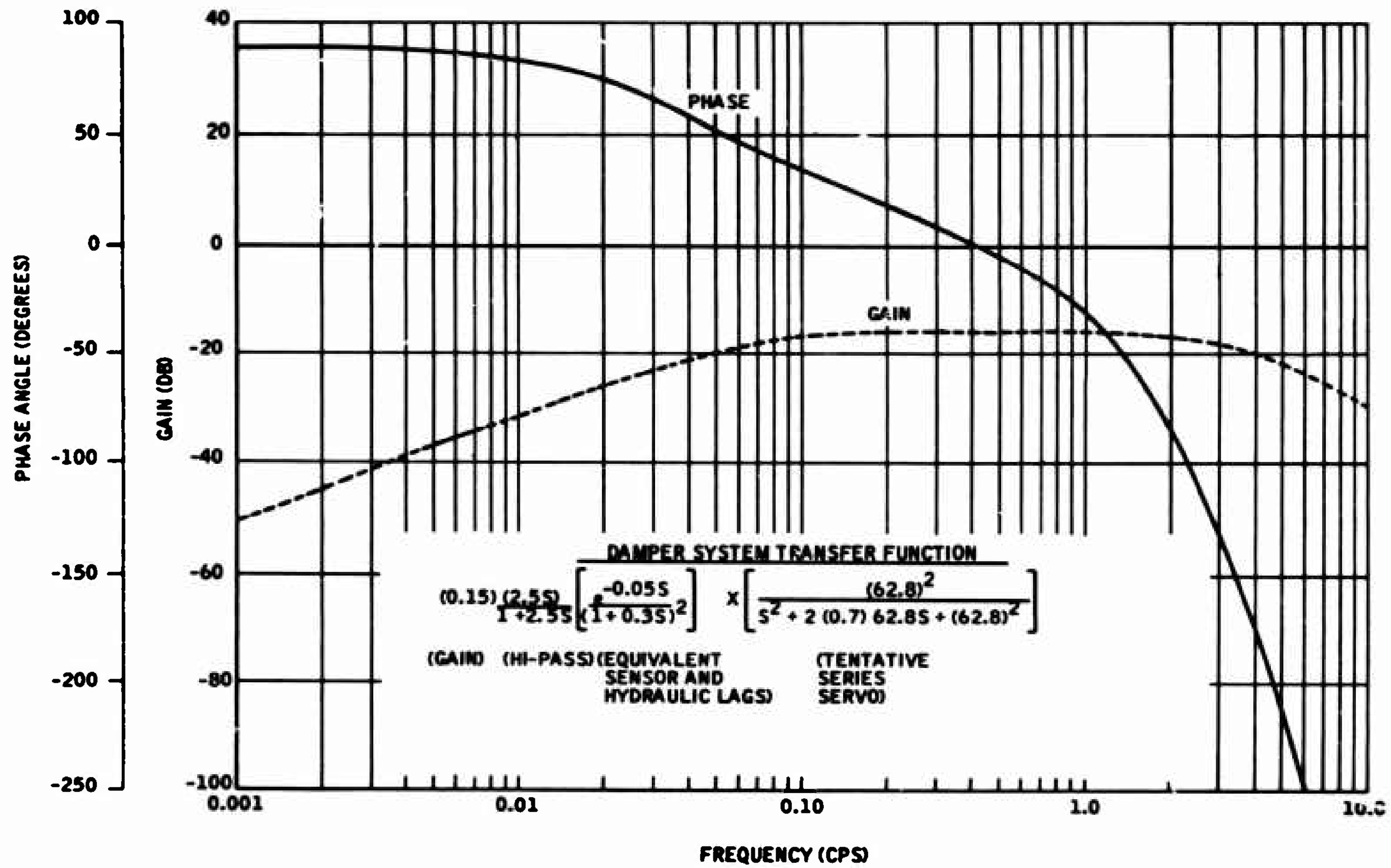


Figure 1. Damper System Design Response.

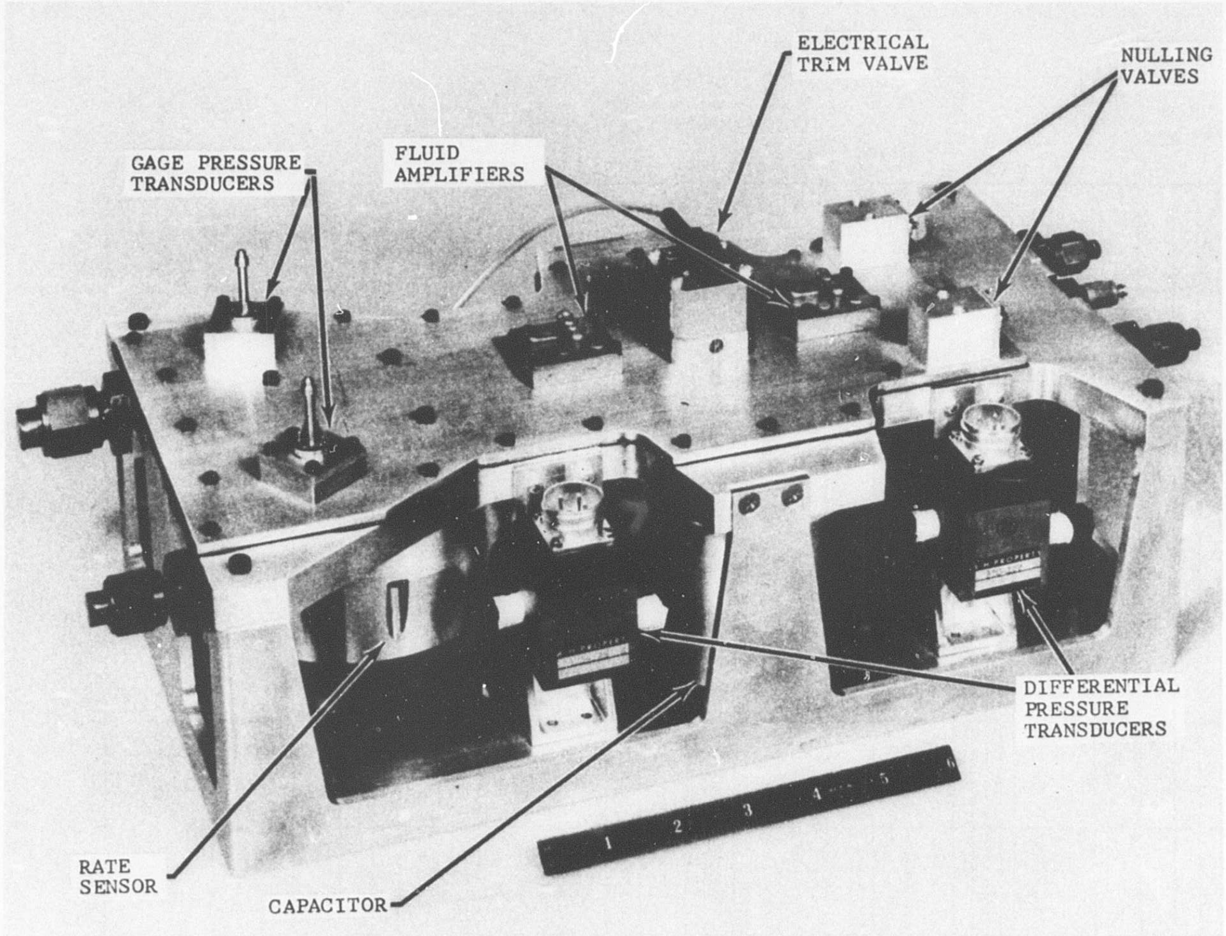


Figure 2. Damper System Basic Unit.

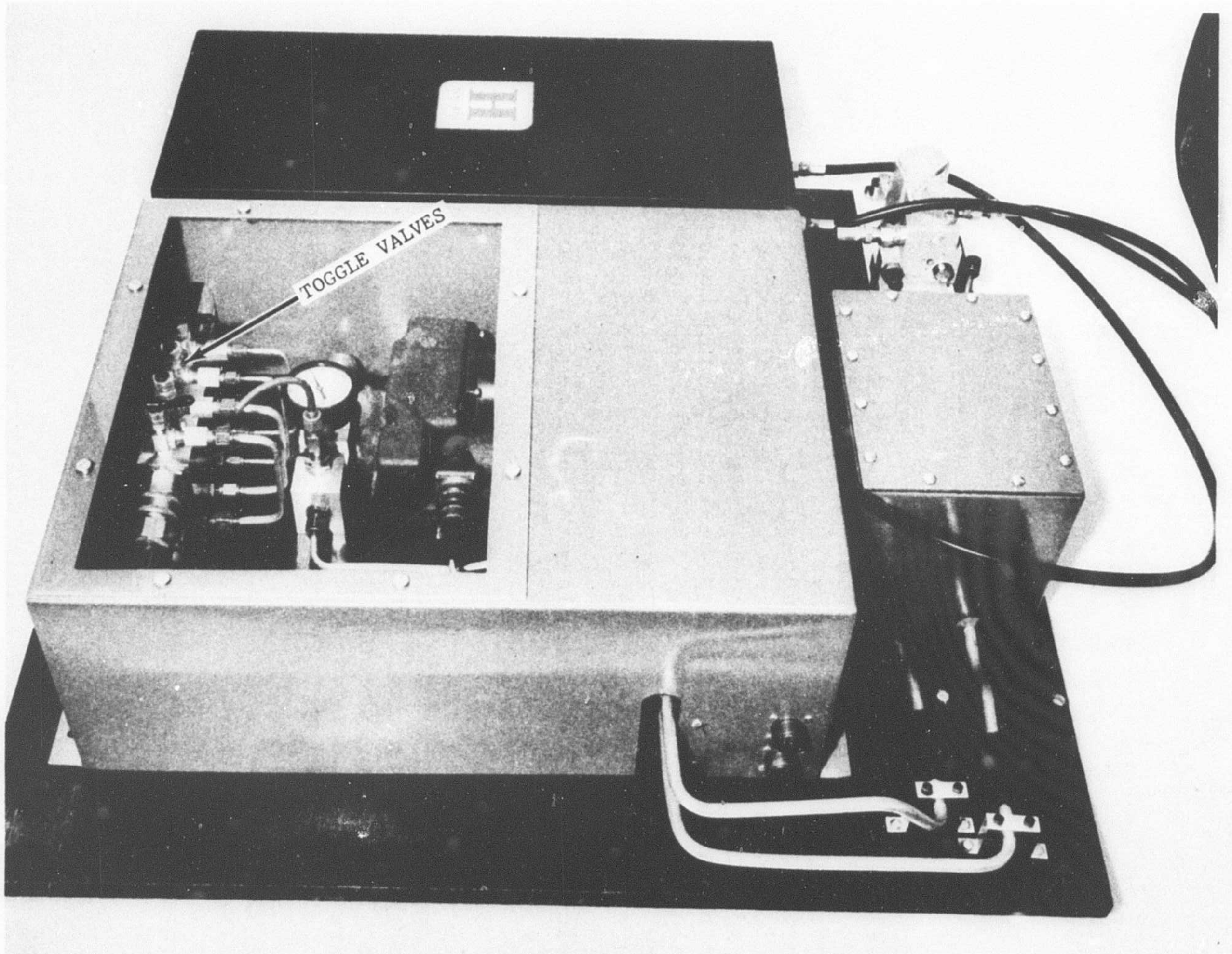


Figure 3. Damper System Packaged for Installation.

Since the fluidic yaw damper package included a self-contained hydraulic system, the installation in the helicopter was relatively simple. After the attachment of the unit to the helicopter cabin floor at a convenient position, electrical power, control circuitry, and hydraulic lines to the yaw damper servo actuator were installed. See Figure 4. The yaw damper servo actuator was located in the directional control system in the position shown in Figure 5 as item number eight.

Few problems were encountered with the installation of the system in the helicopter. The most significant problem was a slight interference between the servo actuator and the airframe at the junction of one of the 1/4-inch diameter hydraulic signal lines and the servo actuator. The final solution was to use a special fitting and a short section of 1/8-inch signal line in this area.

After installation of the system, air was removed from the low-pressure hydraulic system by bleeding the fittings at the actuator and at the aircraft bulkhead (see Figure 4). The low-pressure hydraulic reservoir was maintained at 10 to 15 psig during this bleeding procedure. Since this is a closed hydraulic system, special care was used to remove all entrained air. This was accomplished by removing a sample of oil and by subjecting it to a partial vacuum to remove both entrained and dissolved air. The sample was injected back into the system, and the hydraulic pump was operated for 5 to 10 minutes to mix the fluids thoroughly. This procedure was repeated three times. Further attention to the low-pressure hydraulic system, such as bleeding or the addition of hydraulic oil, was not required after the start of the flight testing.

The trim valve, designed to provide signals which null the system output, was used as an electrical-to-fluid interface for instrumentation calibration. This valve was wired to a switch located on the pilot's control panel as illustrated in Figure 6. Hardover signals were introduced into the system during each preflight instrumentation calibration.

Nulling valves shown in Figure 2 were used in place of the trim valve to obtain a minimum null offset at the original gain setting. These valves are limited in authority to about ±10 percent of actuator stroke. System null offset did change when the system gain was changed. However, no attempts were made to renull the system for each gain setting, since the engage transients were not objectionable.

Gain was increased by increasing flow to the fluidic system. Toggle valves, shown in Figure 3, bypass flow through small

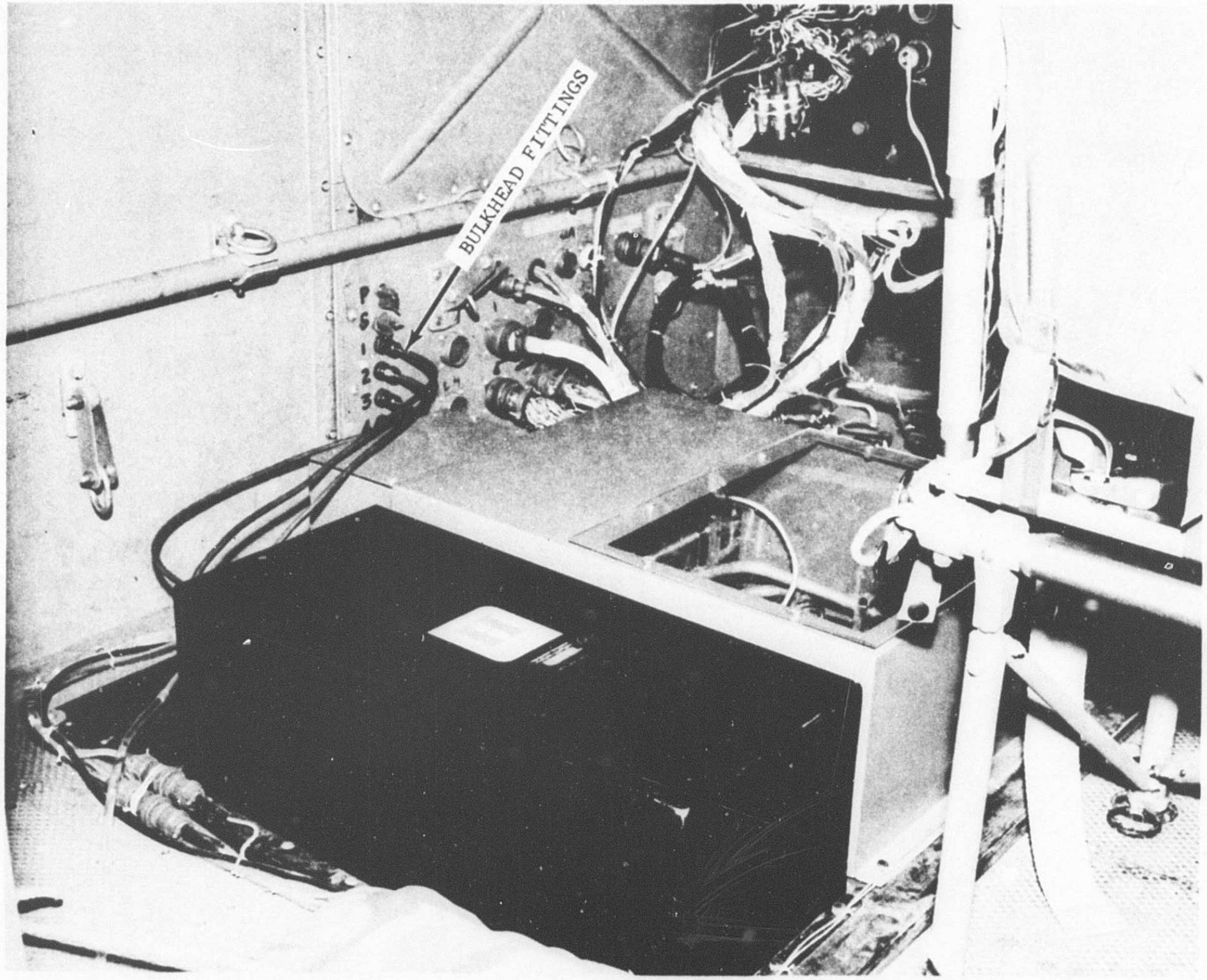
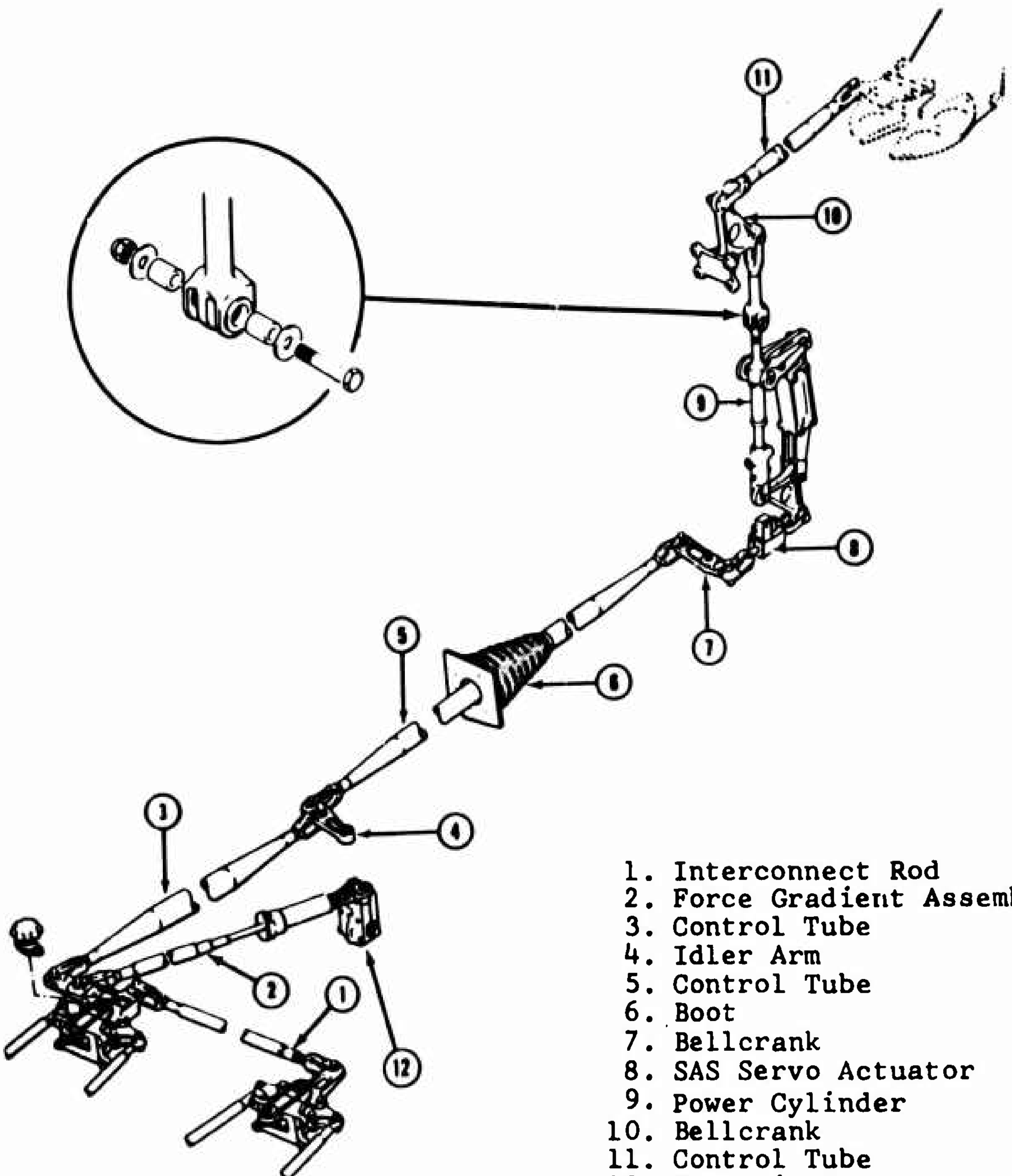


Figure 4. Package Installed on Floor of Helicopter.



1. Interconnect Rod
2. Force Gradient Assembly
3. Control Tube
4. Idler Arm
5. Control Tube
6. Boot
7. Bellcrank
8. SAS Servo Actuator
9. Power Cylinder
10. Bellcrank
11. Control Tube
12. Magnetic Brake

Figure 5. Directional Control System.

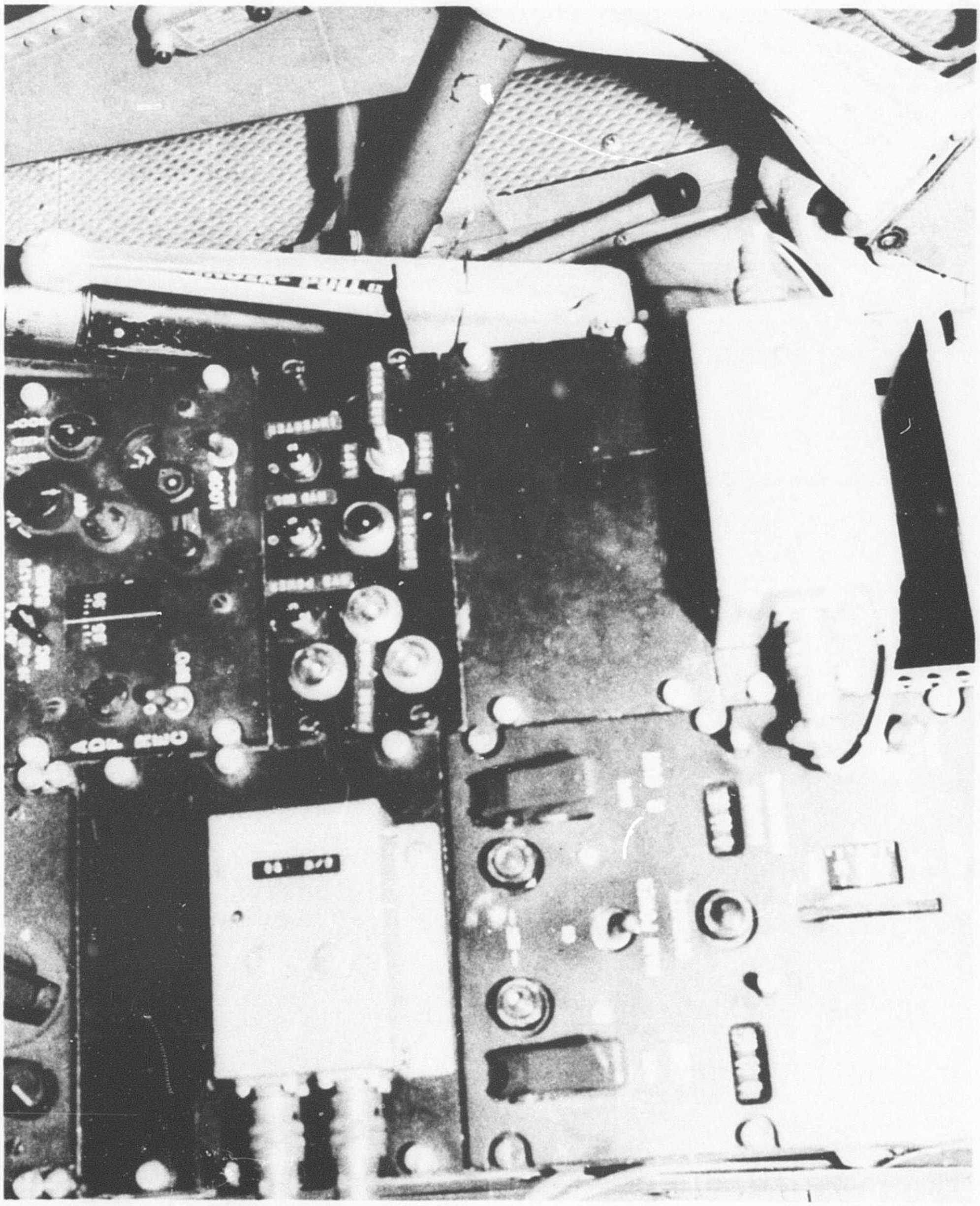


Figure 6. Control Panel on Pilot's Console.

lines which are in parallel with the system. Honeywell pre-shipment test data were used to estimate the gains shown in the following table.

SYSTEM GAIN SETTINGS AND VALVE CONFIGURATIONS		
Gain Setting	Approximate Gain deg rotor/deg/sec	Valve Setting
I	0.15	#1 & #4 closed #2 & #3 open
II	0.30	All closed
III	0.25	#1 & #2 open #3 & #4 closed

The amount of checkout that could be considered was limited by the fact that there was no method for introducing rates into the damper system while it was installed in the aircraft. Plumbing connections between the actuator and the control were checked to determine if this polarity was correct. The control system hydraulic power was turned on, and the actuator was powered with a hydraulic ground cart. Actuator noise and engage transients were observed and judged to be satisfactory.

Two items were checked before, and monitored during, each flight. A reservoir pressure gage indirectly indicated the quantity of fluid in the system. A temperature gage mounted on the pump indicated when the system had reached its design operating temperature. Temperatures in excess of 120°F would indicate that the supply of ice in the heat exchanger had been depleted.

TEST CENTER OF GRAVITY AND GROSS WEIGHT

The test helicopter was weighed after the installation work was completed. The helicopter was ballasted to provide a lift off gross weight of 8447 pounds and a c.g. at Station 126. This weight and forward c.g. location were selected to facilitate comparison of the test results with the data presented in Reference 2.

HANGAR AND TIEDOWN TESTING

After the completion of the installation of the fluidic damper system and the flight test instrumentation, the system was operated in the hangar with the helicopter rotor static and also during a tiedown run.

The hangar testing consisted of 1 hour 22 minutes of system operation. During this time, hydraulic and electrical power were provided for the helicopter by ground power units. All of the helicopter controls were cycled periodically, and oscillograph records were taken to provide a record of system operation. Full throw "hardovers" were introduced into the system by means of the console switches. The system was cycled on and off by removing and applying both electrical and high-pressure hydraulic power. Additionally, the helicopter was yawed slightly by shaking the ship manually with the tail skid.

The system operation was completely stable throughout the hangar test. No change in system noise level or in system operation was recorded. The self-contained low-pressure hydraulic system in the fluidic package maintained a stabilized fluid temperature of 113°F for 1 hour of the 1-hour 22-minute test. At the end of the test, the system temperature was 120°F.

A ground tiedown test followed the completion of the hangar tests and the review of the records. The helicopter and the fluidic damper system were operated for 1 hour 29 minutes. Oscillograph records were taken at intervals to record system steady-state performance and the response of the system to various test conditions. The test conditions that were checked included rudder pedal reversals, hardovers, rotor rpm, engine power sweeps, and engagements and disengagements of the fluidic system by all methods.

As with the hangar tests, no adverse system characteristics were noted, and operation was as expected.

FLIGHT TEST PROCEDURES

Flight evaluation of the damper system began on 5 February, and initial tests to check system and instrumentation operation were performed.

The same basic tests were used for each flight throughout the program. The items listed on the flight test card consisted of step inputs into the directional control system while the helicopter was stabilized in hovering flight and at level

flight speeds of 60, 90, and 110 knots IAS. Other tests, defined in Reference 1, were performed to complete the data requirements.

The initial flights established that "Gain Setting I" (see table on Page 10), that is, the system response per unit of yaw rate that was provided, was so low that the test pilot had difficulty in evaluating the system operation in hovering flight. In forward flight with Gain Setting I, the system operation was definite, but higher system response was desirable. Accordingly, it was decided to take advantage of the variable gain provisions in the package to establish a more optimum gain setting.

Gain Setting II (see table on page 10) provided approximately twice the response per unit of yaw rate that had been programmed by Gain Setting I. This proved to be too high in both hovering and forward flight. In hovering flight, due to the absence of a pilot control loop to differentiate between external disturbances and pilot inputs, the yaw damper system subtracted control from the pilot inputs to a degree that was excessive. This characteristic made control of yaw rate difficult and recovery from hovering turns frequently required full opposite control. In forward flight, the high system response caused objectionably high yaw angular accelerations during conditions of moderate atmospheric turbulence.

Gain Setting III (see table on page 10) was selected as a compromise that could be easily achieved with the existing hardware. Operation of the system was definite enough that the test pilots had no difficulty in detecting a change in airframe response under all flight conditions. The subtraction of pilot control during hovering flight was objectionable but was judged to be an adequate characteristic for evaluation of the conceptual test hardware.

HOVERING FLIGHT

Figures 7 through 10 in Appendix I show the results of control response tests conducted on the basic airframe and repeated with the fluidic system at various gain settings. The degree of increased damping provided by the fluidic system is indicated by the differences in the time required to achieve peak yaw rates. The simple "hardware concept" system did not provide a pilot loop and was not optimized for hovering flight. Even at the compromise setting of "Gain III", the test pilots generally felt that the system's subtracting from the pilot control was objectionable. See Appendix II, pages 34, 37, and 39.

Figure 15 is a time history of the transient response during engagement of the damper system during hovering flight. All transients due to null position errors were insignificant during this program, and no null shifts were encountered.

FORWARD FLIGHT

Figures 7 through 10 also present control response data in forward flight. The additional damping provided by the fluidic system is again apparent from the differences in time required to achieve peak yaw rates and the differences in response per unit of control input.

Figures 13 and 14 show the differences in yaw damping and yawing natural response frequency. The effects of the fluidic system are apparent.

MANEUVERING FLIGHT

The operation of the system during pedal-fixed rolling maneuvers was recorded. The UH-1C, however, has generally good flight characteristics during this type of maneuver without the benefit of yaw stabilization. For this reason, the differences in flight characteristics with the damper on were within flight test measurement accuracy and did not contribute significantly to this evaluation.

LEVEL FLIGHT DIRECTIONAL DAMPING (TURBULENT AIR)

Figures 11 and 12 are time histories of level flight in turbulent air at indicated airspeeds of 110 knots with the fluidic system on and off. The reduction in yaw rate excursions is indicative of additional stabilization provided by the system.

AUTOROTATIONAL ENTRIES

During autorotational entries (see Figure 17) the fluidic system reacted in the proper direction to oppose the yaw rate resulting from the rapid reduction in main rotor torque. The system reduced, to a degree, the amount of pedal control required to maintain heading during the maneuver. The reaction of the system was typical of the characteristics defined by the control response tests.

QUALITATIVE EVALUATION

The pilot reports generated during this program by four different pilots are included in Appendix II of this report. Their comments are brief because the system performed in the

manner intended. There were no in-flight failures such as hardovers or equipment malfunctions. The absence of a pilot control loop precludes a direct comparison with present-day electrohydraulic damper systems. The test hardware did not demonstrate any inherent characteristics that might limit the application of fluidic stabilization systems in the helicopter environment.

VIBRATION

Sufficient vibration data were analyzed (see Figure 18) to establish that the vibration environment was typical of UH-1C helicopters. During the test program, the fluidic system showed no response to these vibration levels.

CONCLUSIONS

As a result of the test program described in this report, the following conclusions have been reached:

1. Installation of the package, a feasibility version representative of fluidic technology, was relatively simple due to the minimum interfaces between the package and the aircraft systems. Evaluation of the compatibility of a fluidic stabilization system and helicopter hydraulic systems was beyond the scope of this program.

2. The package provided by Honeywell, Inc., functioned in general according to the performance requirements which had been previously defined by USAAVLABS Report 66-87 and by the direct contact between Honeywell, Inc., and BHC.

3. System noise level (i.e., random motion) was well within tolerable levels and was not discernible in flight.

4. The system, as packaged, required a heat exchanger to control fluid temperature within the desired tolerances. While temperature control in this manner is a minimal problem for test hardware, an integrated system would have to be capable of providing good performance at any fluidic temperature that would be encountered under normal operating conditions.

5. The ground adjustable gain provisions in the test hardware facilitated the conduct of the evaluation by allowing "compromise" gain settings.

6. The system maintained good null balance throughout the flight program without readjustment. Engagement and disengagement transients were well within acceptable limits.

7. The absence of a pilot loop caused the damper system to decrease the helicopter yaw response following small-amplitude step displacement of the directional pedals.

8. A significant increase in yaw damping was provided by the system.

9. The system was effective in improving lateral-directional damping and in reducing pilot workload in forward flight under conditions of moderate turbulence.

10. The maneuvering flight characteristics (i.e. adverse yaw during rolling maneuvers) of the basic helicopter were not measurably changed by the fluidic yaw damper. The basic UH-1C adverse yaw characteristics are good; therefore, little improvement could be expected.

11. The system responded properly during autorotational entries to assist the pilot with yaw control of the helicopter heading within the limits of the authority of the damper servo.

12. No malfunctions were experienced during the 8.5-hour flight program.

13. Pilot acceptance of the system was good, based on the consideration that it was a simple rate damper without pilot loops, quickening, and other sophisticated features of current electronic SCAS systems. If a fluidic system were to be incorporated into a production helicopter design, the additional features would have to be present to obtain pilot ratings equivalent to those provided by current electronic SCAS.

14. The vibration environment of the fluidic system during the tests was typical of UH-1C helicopters. No detectable system response to the vibration environment was encountered.

15. None of the test results revealed any factors that might limit the application of fluidic systems in a helicopter environment. The performance and reliability of the "feasibility" package were much better than expected and helped to create a favorable overall impression of the concept.

16. Use of the electrical trim valve for instrumentation calibration demonstrated the capability of this system to interface with an electronic outer loop control.

REFERENCES

1. Ward, Hugh, Flight Test Plan for the Honeywell, Inc. Fluidic Yaw Damper, Bell Helicopter Company Report No. 205-947-074, November 18, 1967.

2. Schroers, Laurel G., et al., Engineering Flight Test of the UH-1B Helicopter Equipped with the Model 540 Rotor, USATECOM Report No. 4-4-0108-03, USAAVNTA Project No. 64-28, U. S. Army Aviation Test Activity, Edwards Air Force Base, California, December 1966.

3. Stoker, James R., Detail Specification for UH-1B Utility Helicopter, Bell Helicopter Company Report No. 204-947-125, May 20, 1963.

4. Burton, R. V., et al., Fluid State Hydraulic Damper, U. S. Army AVLABS Report 66-87, February 1967.

APPENDIX I
PLOTTED TEST DATA AND RESULTS

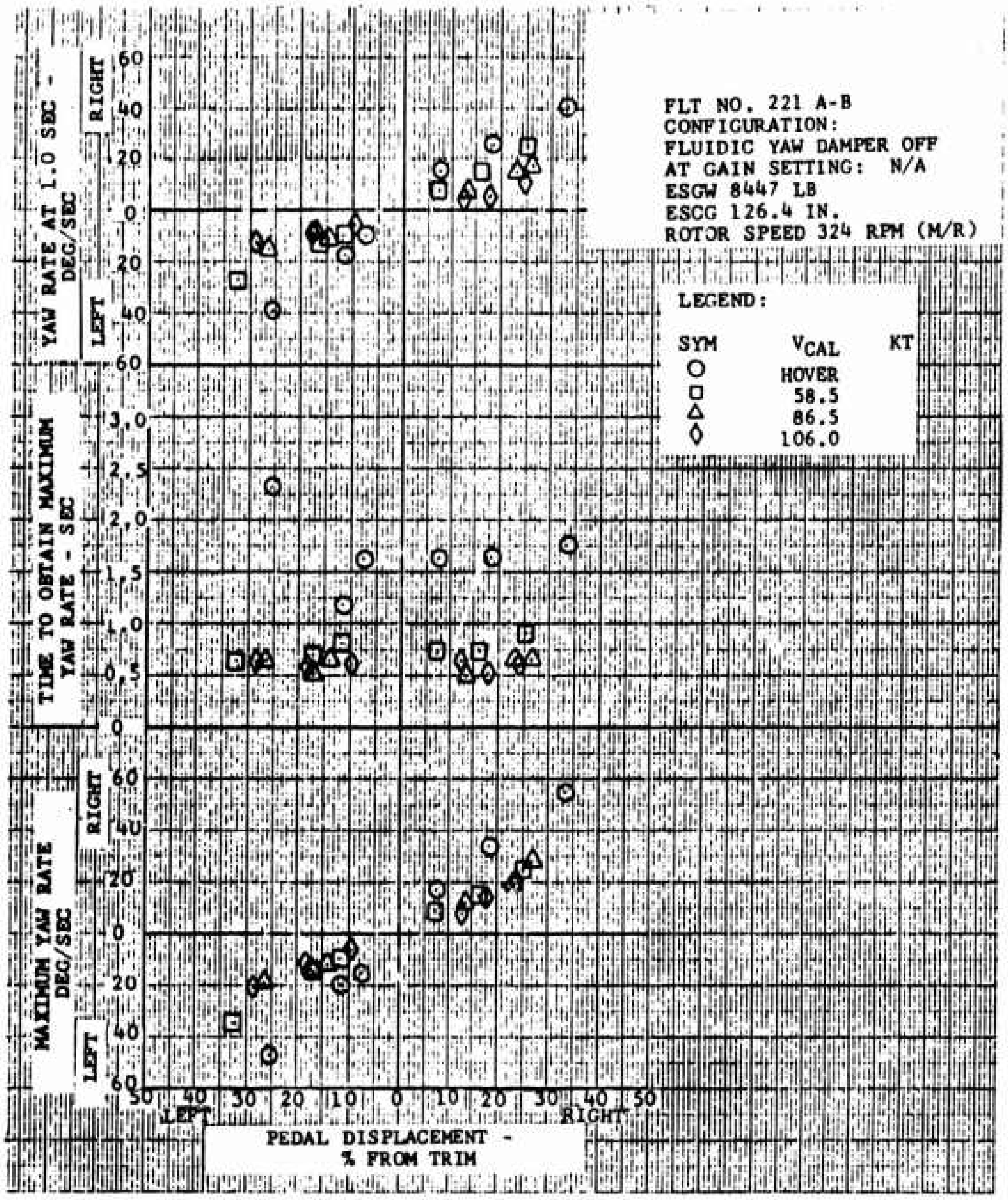


Figure 7. Directional Control Response With Fluidic Damper Off.

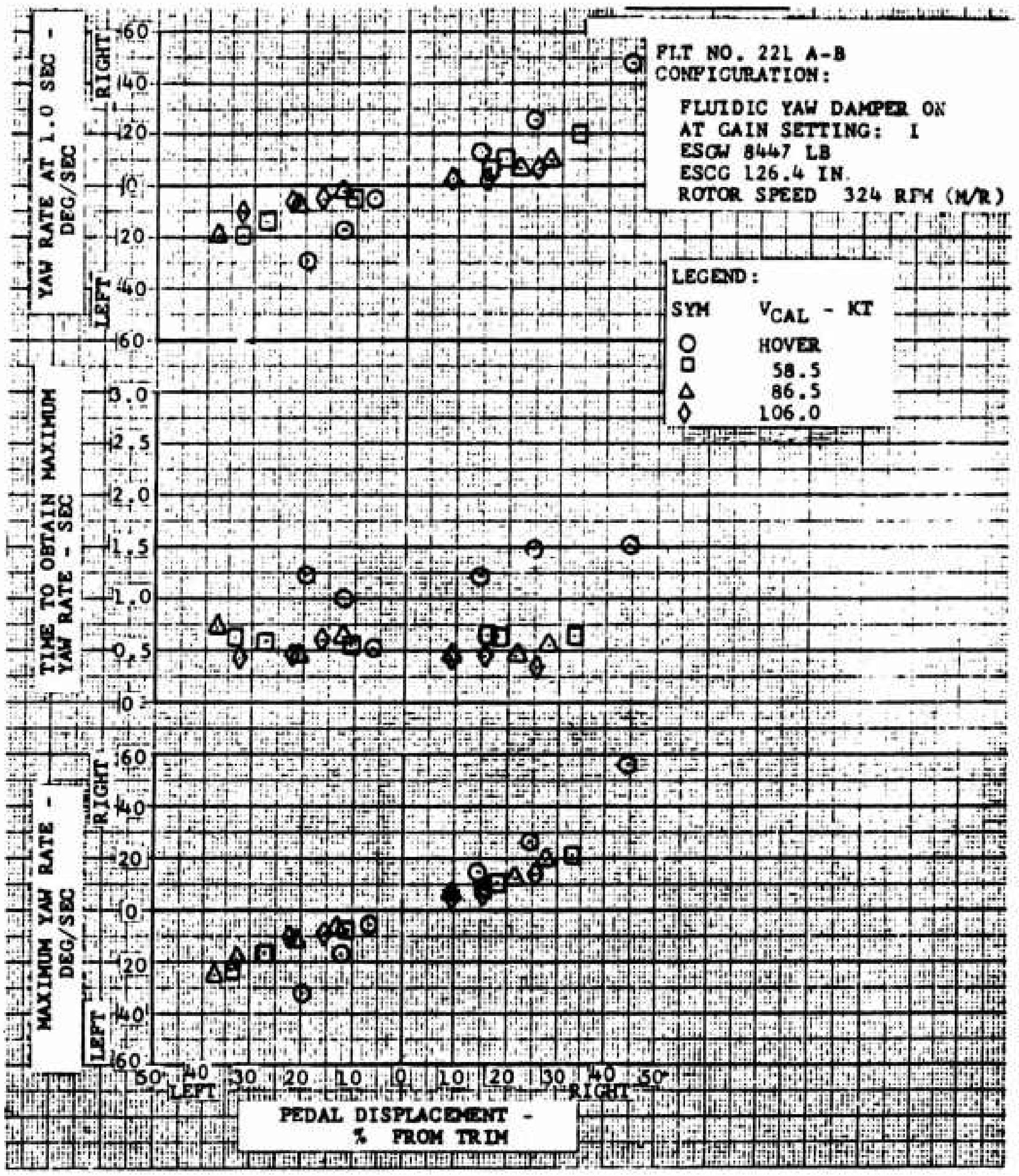


Figure 8. Directional Control Response With Fluidic Damper On.

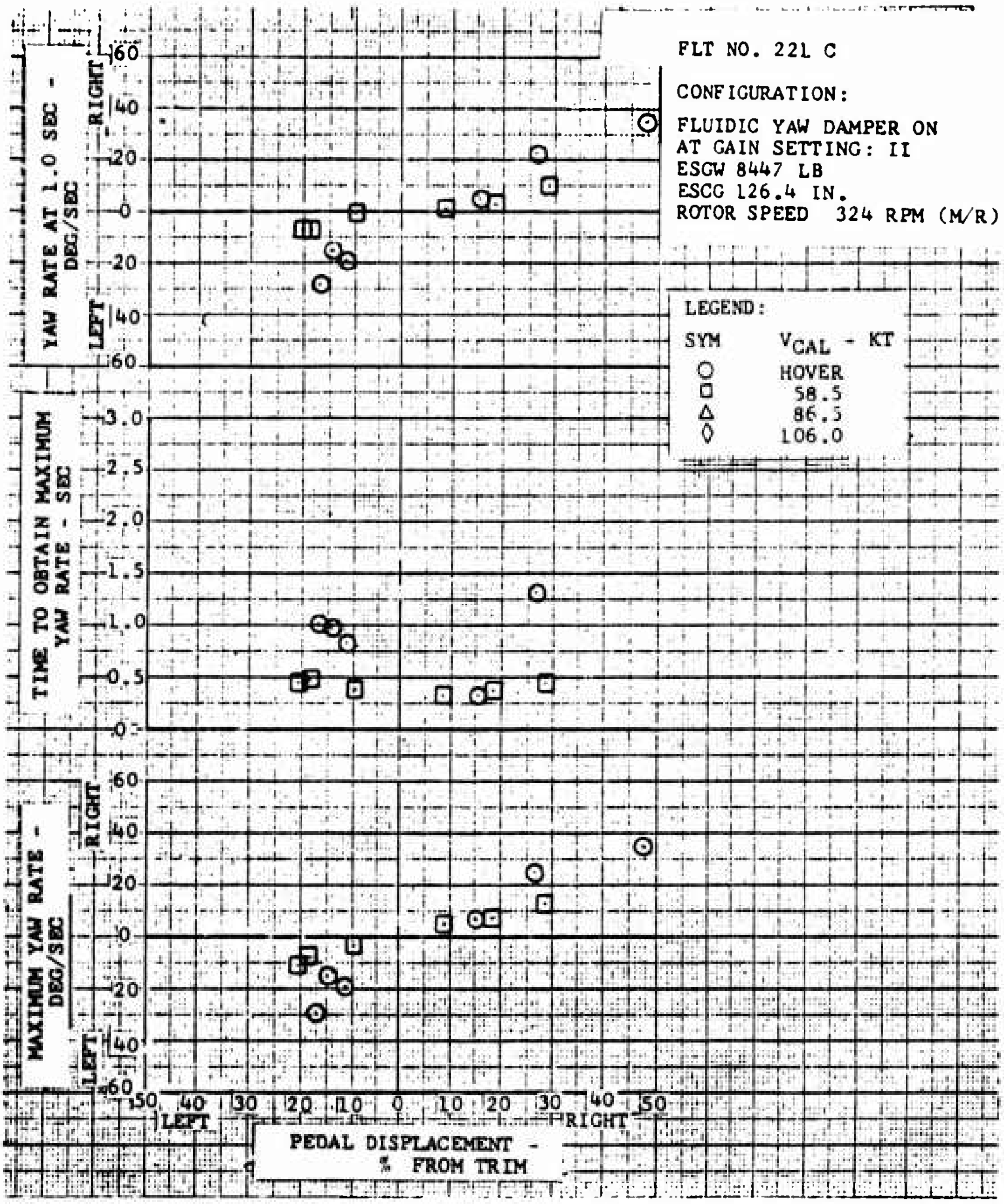


Figure 9. Directional Control Response With Fluidic Damper On.

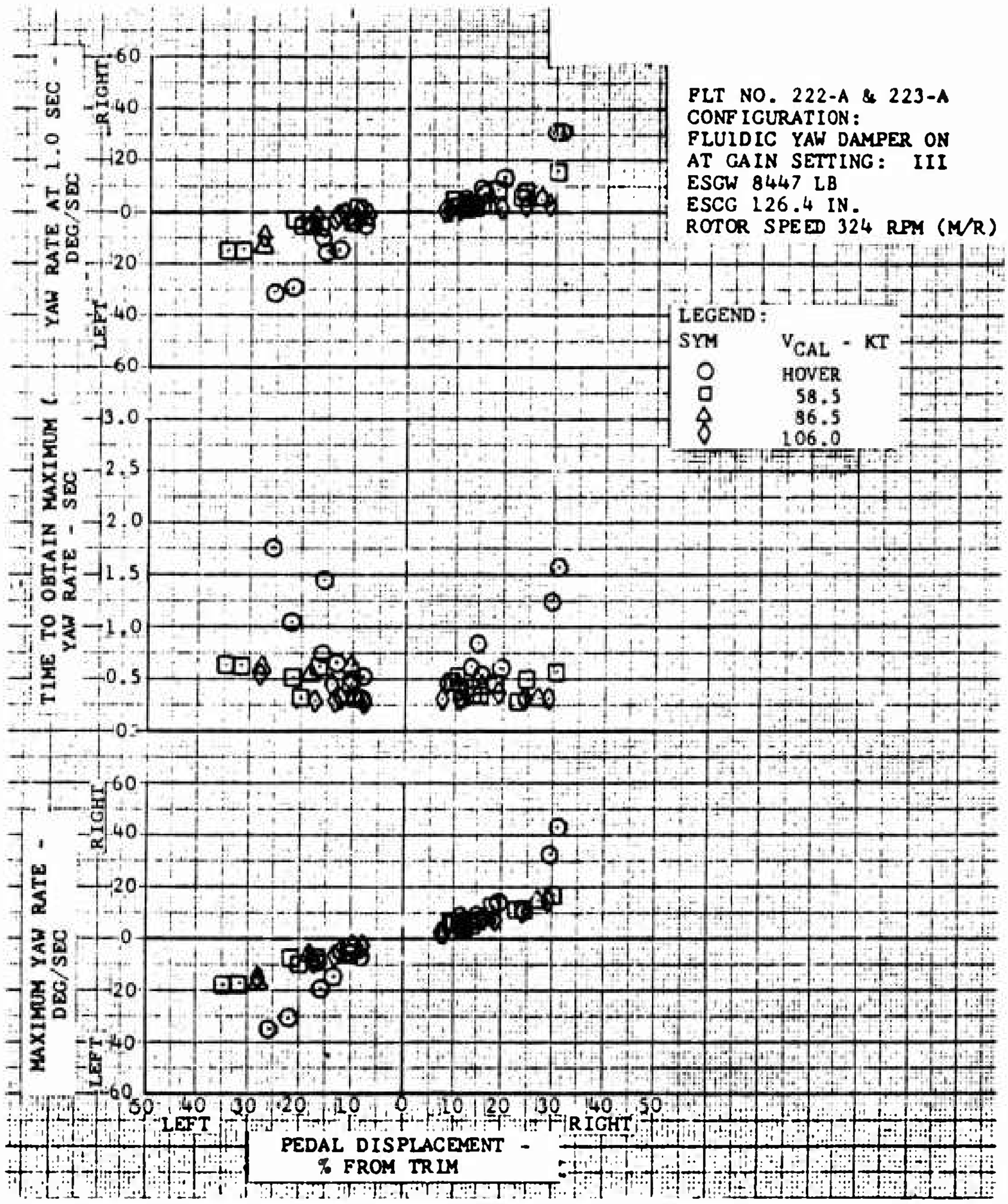


Figure 10. Directional Control Response With Fluidic Damper On.

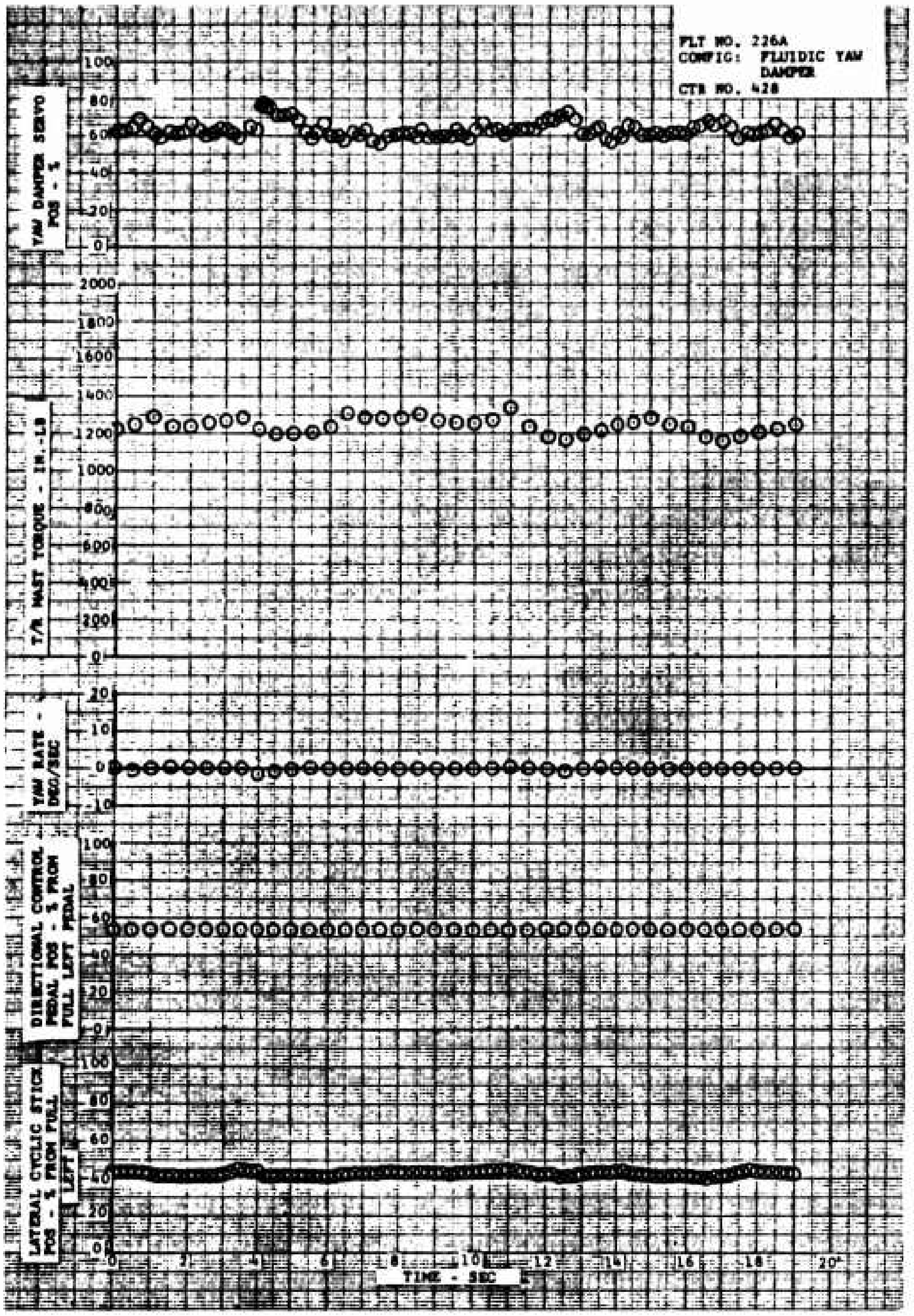


Figure 11. Time History of 110 Knots Level Flight With Fluidic Damper On.

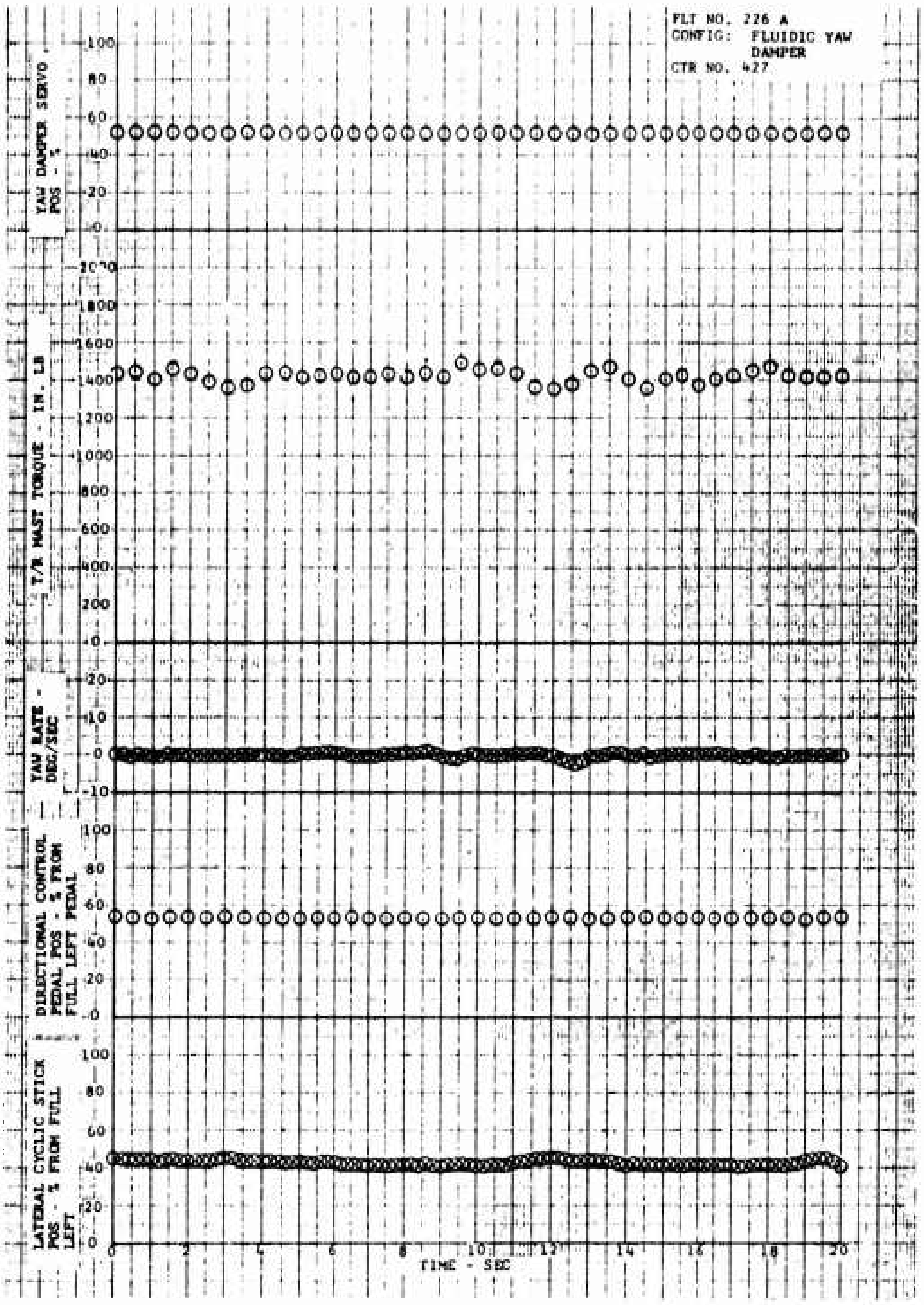


Figure 12. Time History of 110 Knots Level Flight With Fluidic Damper Off.

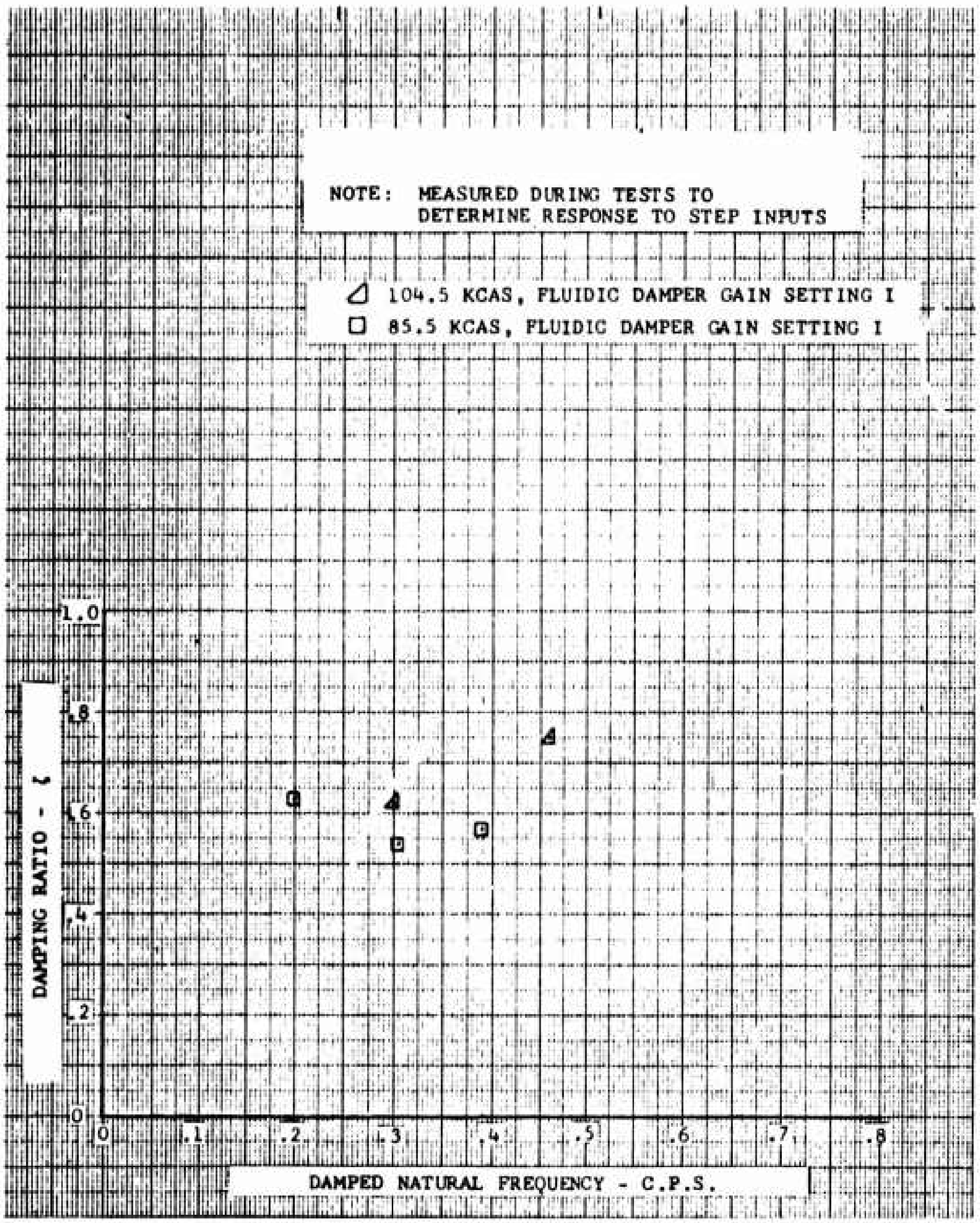


Figure 13. Directional Damping - Gain Setting I.

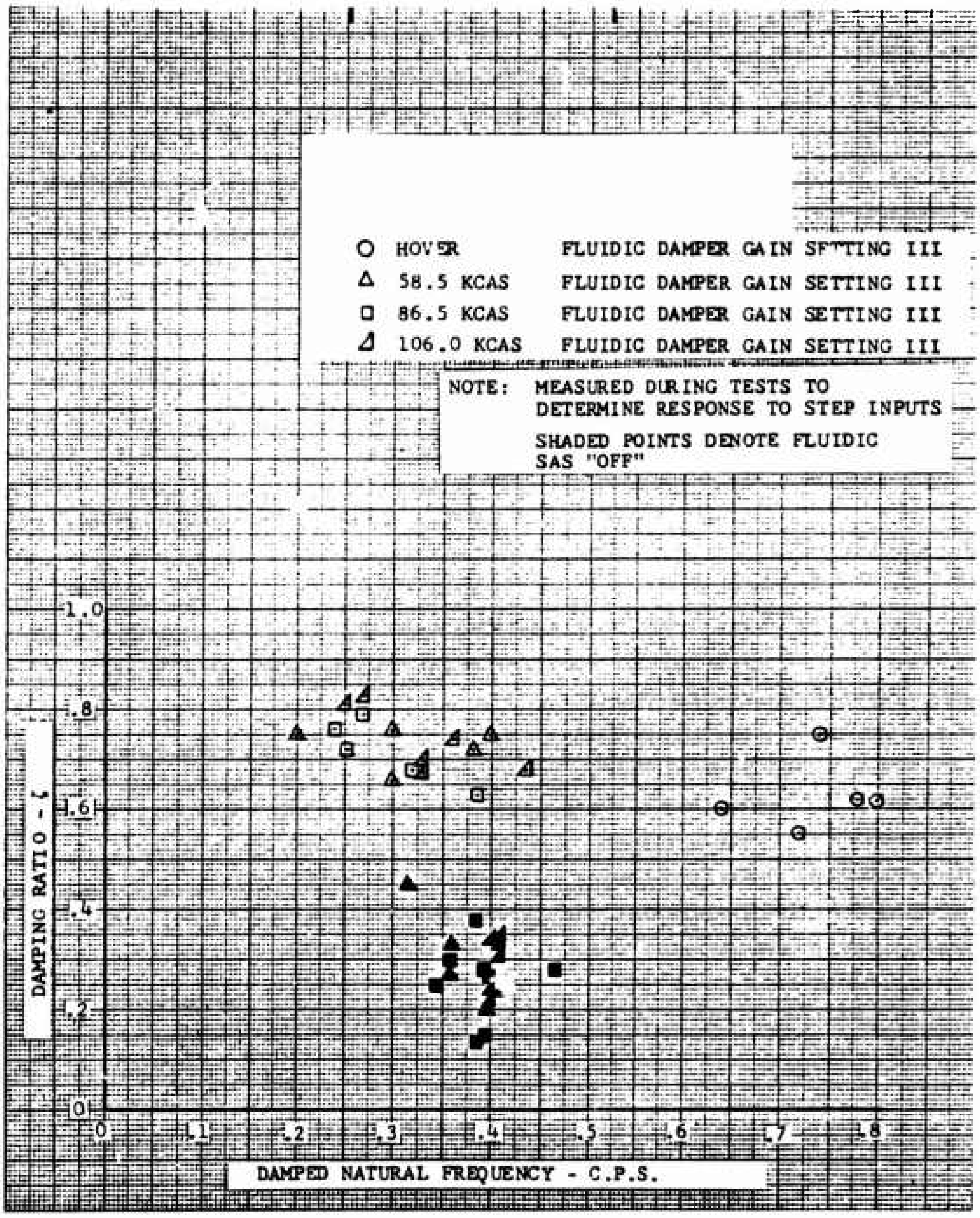


Figure 14. Directional Damping - Gain Setting III.

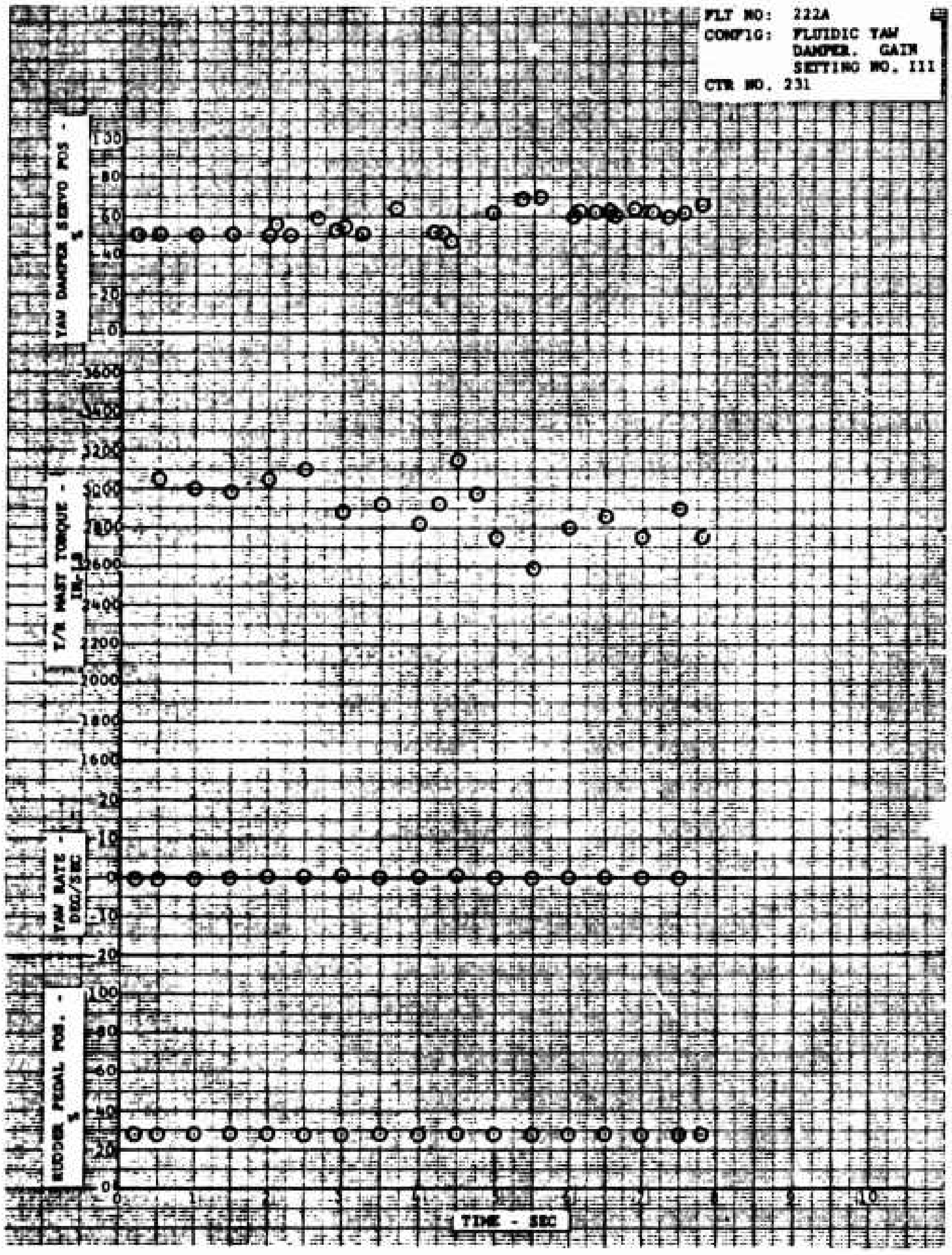


Figure 15. Time History of Hover From 2.0 Seconds Before Engagement of Fluidic Yaw Damper.

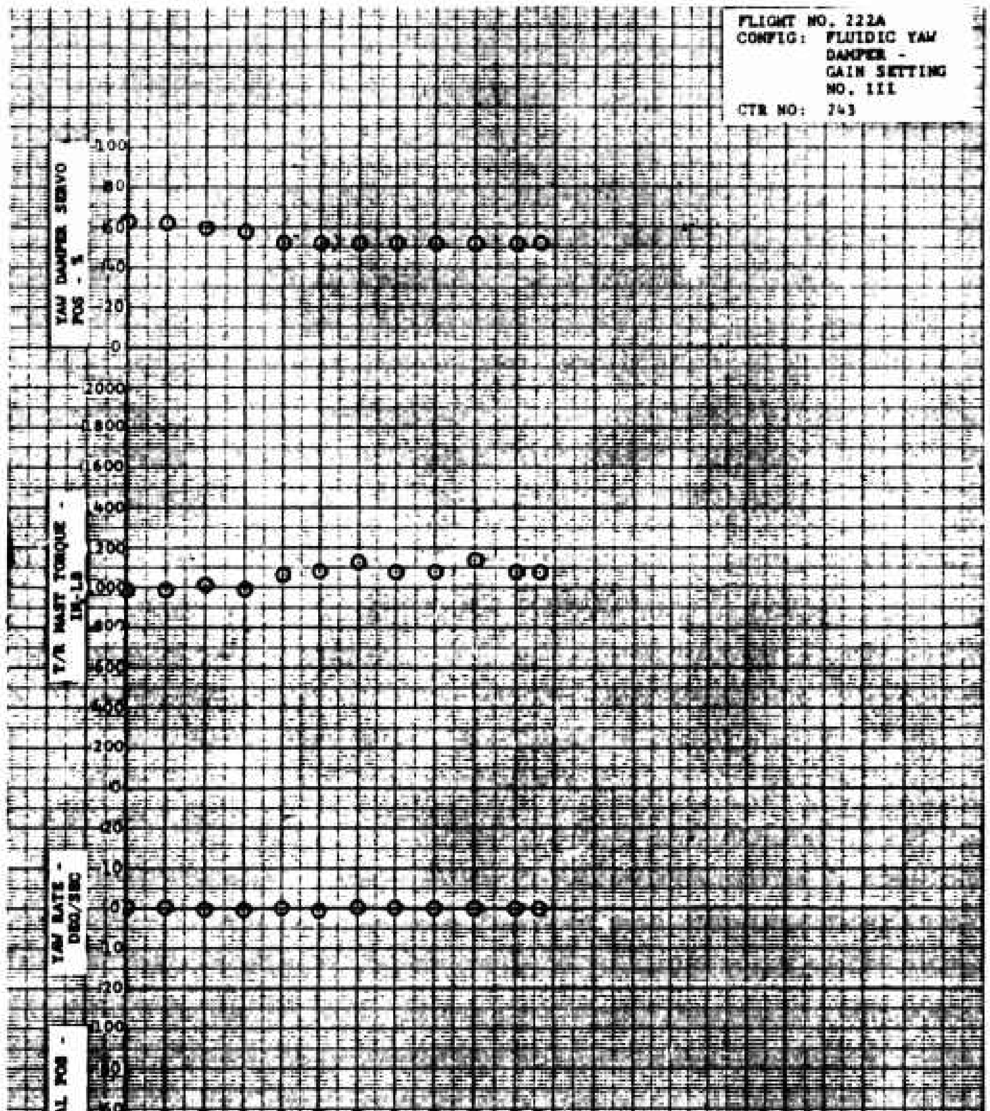


Figure 16. Time History of Level Flight at 60 Knots IAS From 2.0 Seconds Before Disengagement of Fluidic Yaw Damper.

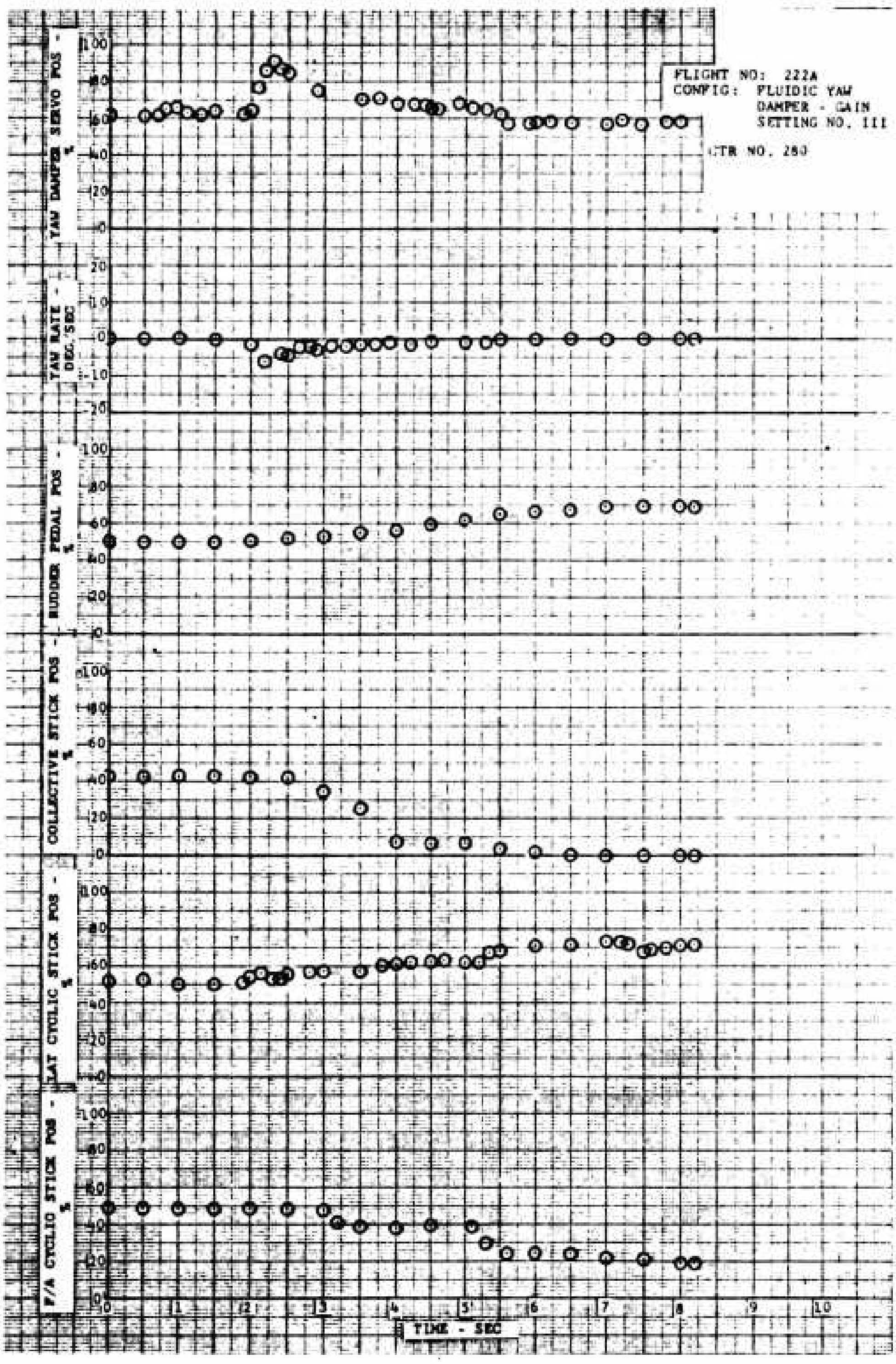


Figure 17. Time History of Throttle Chop at 110 Knots IAS From 2.0 Seconds Before Engine Power Reduction - Fluidic Yaw Damper On.

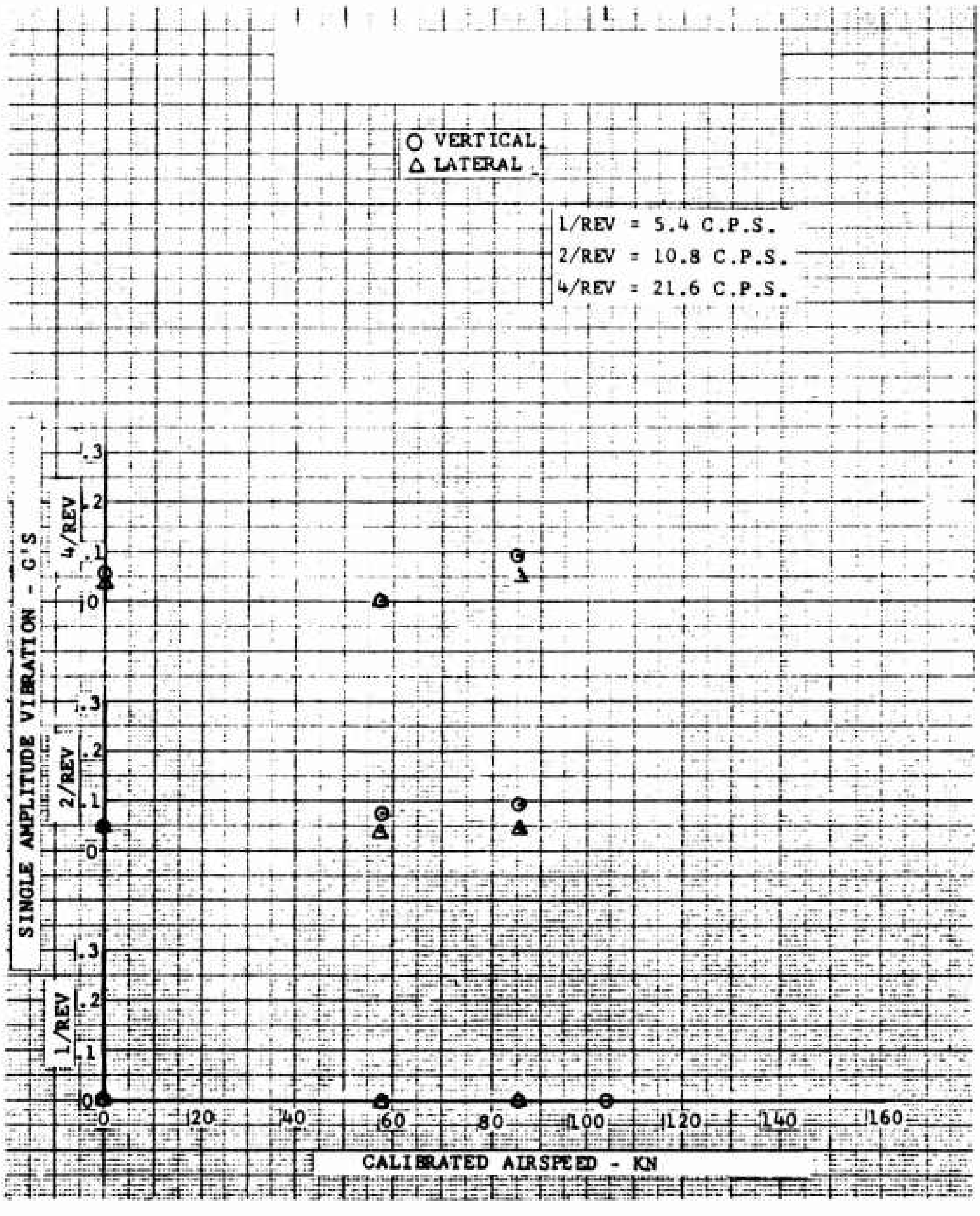


Figure 18. Fluidic Package Vibration Environment.

APPENDIX II

PILOT REPORTS

BY: T. Gerard — DATE: 2-9-68	PILOT REPORT	MODEL: UH-1C		PAGE: 1
CHECKED: — DATE: 2/10/68		HELICOPTER NUMBER: 1226 (64-14102)		
PILOT: Gerard		PLACE: Arlington		
CREW:		FLIGHT NO.:	GROUND RUN NO.: 43 2-3-68	
WEATHER: 250 ⊘	PRESSURE ALT.: 380'	O. A. T.: 6°C	WIND: S 6-12 K	
PURPOSE: Fluidic Yaw Damper Check				
ENG. REPORT NO.:	TIME TAKE OFF:	TIME LANDING:	DURATION: 1.5	
C.G. FROM STA. 0.:	G.W. LBS.:	TOTAL FLIGHT TIME TO DATE:	TOTAL ENGINE TIME TO DATE: 34.3	

CHANGES SINCE LAST FLIGHT

1. Daily inspection completed.
2. Removed all ballast.
3. Fluidic control system installed.
4. Tail rotor slip ring installed.
5. Removed rate switching gyro S/N AF63-4400 (use on AH-1G 20004)
6. Installed instrumentation for fluidic control system per Engr. Requests (fluidic yaw damper system).
7. Removed whip antenna and mount and stowed wiring.
8. Removed XM-30 wiring baggage compartment.
9. Installed the following in C/P panel: A/S indicator, S/N 2171, R/C ind. VS57421, Alti. S/N 31208 and leak checked system after installation.
10. Tail rotor rigging as follows: full left pedal 20-3/8°, full right = 6-1/8° and neutral pedal 6-1/2°.
11. Installed tiedown link.

The purpose of this run was to operate the fluidic yaw damper for an extended period of time. Records were taken of rudder inputs, engagements, disengagements and hardovers during the ground run. Operation was satisfactory on the ground.

86:TG:bt-10757

BY: T. Gerard	DATE: 2-9-68	MODEL: UH-1C	PAGE: 1
CHECKED: [illegible]	DATE: 2/10/68	HELICOPTER NUMBER: 1226 (64-14102)	
PILOT: Gerard	PILOT REPORT	PLACE: Arlington	

CREW:		FLIGHT NO.: 219 2-3-68	GROUND RUN NO.:
WEATHER: CAVU	PRESSURE ALT.: 360'	O. A. T.: 18°C	WIND: S 20-25 K

PURPOSE: Fluidic Yaw Damper Evaluation

ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION
			0.1

C.G.	FROM STA. O.	G.W.	TOTAL FLIGHT TIME TO DATE	TOTAL ENGINE TIME TO DATE
Aft	133	6800 LBS.	372.7	

CHANGES SINCE LAST FLIGHT

A: 1. Removed tiedown link assembly.

The purpose of this flight was to obtain in-flight data on the fluidic yaw damper. Records were taken in hover of engagements, disengagements, rudder step inputs and power changes. There was no apparent instability; in fact it was difficult to tell that it was working in hover. The air was quite gusty.

86:TG:bt-10756

BY	DATE		MODEL	PAGE
W. Quinlan	2-14-68	PILOT REPORT	UH-1C	1
CHECKED	DATE		HELICOPTER NUMBER	
[illegible]	2-19-68		1226 (64-14102)	
PILOT			PLACE	
Quinlan			Arlington	

CREW	FLIGHT NO.	GROUND RUN NO.
	220 2-5-68	

WEATHER	PRESSURE ALT.	O. A. T.	WIND
45 O	300'	14°C	N 15 K

PURPOSE

Fluidic Yaw Damper Evaluation

ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION
			0.3

C.G.	FROM STA. O.	G.W.	TOTAL FLIGHT TIME TO DATE	TOTAL ENGINE TIME TO DATE
Fwd	126	8447 LBS.	373.0	

CHANGES SINCE LAST FLIGHT

1. Daily inspection completed.
2. Installed medical attendant's seat.
3. Installed rate gyro package.
4. Weighed ship.
5. Installed rate switching from Ship #1092.
6. See carry over.
7. Ballasted as follows: 200# at Sta. 7.0, 600# at Sta. 86.0.

B: 1. Fueled to 1500#.

This flight was made in connection with the fluidic yaw damper system evaluation, and was for the purpose of instrumentation check out.

86:WTQ:bt-10797

BY W. Quinlan	DATE 2-14-68	PILOT REPORT	MODEL UH-1C	PAGE 1
CHECKED [illegible signature]	DATE 2-14-68		HELICOPTER NUMBER 1226 (64-14102)	
PILOT Quinlan			PLACE Arlington	
CREW			FLIGHT NO. 221 2-6-68	GROUND RUN NO.
WEATHER CAVU		PRESSURE ALT. 160'	O. A. T. 12°C	WIND NW 5-10 K
PURPOSE Fluidic Yaw Damper Evaluation				
ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION A:.6-B:.6-C:.7	
C.G. Fwd FROM STA. O. 126.4	G.W. 8447 LBS.	TOTAL FLIGHT TIME TO DATE 374.9	TOTAL ENGINE TIME TO DATE	
CHANGES SINCE LAST FLIGHT 1. Daily inspection completed.				

<u>Flights A and B</u>: These flights were made for the purpose of evaluating the fluidic yaw damper system.

The first configuration was evaluated in hover and at three forward speeds. Quantitative data were recorded during pedal step inputs at three amplitudes and in release from steady state side slip conditions.

Qualitatively, the system was found to function essentially as was intended, however, the gain of the system was obviously too low.

<u>Flight C</u>: Prior to Flight C, the gain of the system was doubled. This configuration was then evaluated in the same manner and the same data points recorded as in the previous configuration.

Qualitatively, the gain was too high in this configuration, in that the system was too tight in rough air, producing lateral accelerations which were uncomfortable.

86:WTQ:bt-10796

BY R. Kjellander DATE 2-9-68	PILOT REPORT		MODEL UH-1C	PAGE 1
CHECKED DATE			HELICOPTER NUMBER 1226 (64-14102)	
PILOT Kjellander			PLACE Arlington	
CREW			FLIGHT NO. 222 2-7-68	GROUND RUN NO.
WEATHER CAVU		PRESSURE ALT. 170'	O. A. T. 8°C	WIND 15-20 K N
PURPOSE Fluidic Yaw Damper Evaluation				
ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION A:1.0-B:0.3	
C.G. Fwd. FROM STA. 0. 116.4	G.W. 8447 LBS.	TOTAL FLIGHT TIME TO DATE 376.2	TOTAL ENGINE TIME TO DATE	
CHANGES SINCE LAST FLIGHT A: 1. Daily inspection completed.				

The purpose of Flights A and B was to obtain dynamic directional stability data using the Honeywell Fluidic Yaw Damper System. Qualitatively, the system functioned as designed in this configuration; however, in this writer's opinion, the system was too loose (low gain) during hover, and too tight (high gain) in forward flight, causing jerky movements in turbulent air. Damping after a 10 to 15° yaw input was good, as the system damped yaw oscillations after 1 or 2 cycles. However, you can feel the system feeding back through the anti-torque pedals.

Data is on file in Flight Test.

86:RGK:bt-10762

BY: R. Kjellander — DATE: 3-8-68	PILOT REPORT	MODEL: UH-1C		PAGE: 1
CHECKED — DATE		HELICOPTER NUMBER: 1226 (64-14152)		
PILOT: Kjellander		PLACE: Arlington		
CREW		FLIGHT NO.: 223 2-8-68	GROUND RUN NO.	
WEATHER: CAVU	PRESSURE ALT.: 200'	O. A. T.: +1	WIND: N 5 K	
PURPOSE: Fluidic Yaw Damper Evaluation				
ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION: A:.2-B:.4	
C.G. Fwd — FROM STA. O. 126.4	G.W. 8447 LBS.	TOTAL FLIGHT TIME TO DATE: 376.8	TOTAL ENGINE TIME TO DATE	
CHANGES SINCE LAST FLIGHT: 1. Daily inspection completed.				

The purpose of this flight was to obtain data on the fluidic yaw damper as installed in this aircraft. Data was taken at a hover while making step inputs and pedal reversals.

Data is on file in Flight Test.

86:RCK:bt-10955

BY: W. Quinlan	DATE: 2-26-68	PILOT REPORT	MODEL: UH-1C	PAGE: 1
CHECKED:	DATE:		HELICOPTER NUMBER: 1226 (64-14102)	
PILOT: Quinlan			PLACE: Arlington	
CREW: Long			FLIGHT NO.: 224 2-9-68	GROUND RUN NO.:
WEATHER: CAVU		PRESSURE ALT.: 260'	O. A. T.: 15°C	WIND: S 6-10 K
PURPOSE: Fluidic Yaw Damper Evaluation				
ENG. REPORT NO.:	TIME TAKE OFF:	TIME LANDING:	DURATION: A:.9-B:.6,	
C.G.: Fwd. FROM STA. 0.: 126.4	G.W.: 8447 LBS.	TOTAL FLIGHT TIME TO DATE: 378.3	TOTAL ENGINE TIME TO DATE:	

CHANGES SINCE LAST FLIGHT

1. Daily inspection completed.
B: 1. Fueled to 1500# indicated.
C: 1. Fueled to 1500# indicated.

This flight was made for the purpose of continuing the evaluation of the fluidic yaw damper system.

Data were recorded in the same maneuvers as on previous flights. Qualitatively, the system appeared to function essentially as intended.

86:WTQ:bt-10872

BY / DATE		MODEL	PAGE
G. Colvin 2-15-68	PILOT REPORT	UH-1C	1
CHECKED / DATE		HELICOPTER NUMBER 1226 (64-14102)	
PILOT Colvin		PLACE Arlington	

CREW	FLIGHT NO. 225 and 226	GROUND RUN NO. 2-12-13/68

WEATHER	PRESSURE ALT.	O. A. T.	WIND
CAVU			

PURPOSE: Fluidic Yaw Damper Evaluation

ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION
			Flt. 225:.9; Flt.226:.9

C.G. FROM STA. O.	G.W. LBS.	TOTAL FLIGHT TIME TO DATE	TOTAL ENGINE TIME TO DATE
		41.3	

CHANGES SINCE LAST FLIGHT

Flight 225: A: 1. Installed new flight idle detent stop.
2. Daily inspection completed.
B: 1. Fueled to 1500#.
Flight 226: 1. Daily inspection completed.

Flights 225A and 226A:

The purpose of these flights was to quantitatively evaluate the directional response of the aircraft with the M/H Fluidic Damper installed. Since this system is a parallel system, it does take control away from the pilot which is undesirable. The system appeared to function well; however, no firm opinion can be made on gain, settings, etc., since a mission using the damper has not been described.

86:GLC:bt-10805

BY 2-26-68 DATE L. Rohrbough	PILOT REPORT	MODEL: UH-1C	PAGE 1
CHECKED / DATE R 3-5-68		HELICOPTER NUMBER 1226 (64-14102)	
PILOT Rohrbough		PLACE Arlington	
CREW		FLIGHT NO. 227 2-15-68	GROUND RUN NO.

WEATHER	PRESSURE ALT.	O. A. T.	WIND
6 0	280'	7°	N 10 K

PURPOSE
Fluidic Yaw Damper Evaluation

ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION
			0.8

C.G.	FROM STA. 0.	G.W.	TOTAL FLIGHT TIME TO DATE	TOTAL ENGINE TIME TO DATE
Fwd	124.6	8447 LBS.	380.4	

CHANGES SINCE LAST FLIGHT
A: 1. Daily inspection completed.

The purpose of this flight was to demonstrate the Fluidic Yaw Damper to Mr. George Fosdick of Av-Labs.

The realms of flight shown were steady state cruise with displacements and return to trim with the system on and off. Power changes from cruise to climb and to low power were also shown. Hovering inputs and crosswind hovering were demonstrated.

Mr. Fosdick appeared to be impressed with the system in general and satisfied with the function of the Fluidic Yaw Damper System as installed in this helicopter.

86:LOR:bt-10869

BY: R. Erhart — DATE: 2-19-68	PILOT REPORT	MODEL: UH-1C — PAGE: 1
CHECKED: [illegible] — DATE: 3-8-8		HELICOPTER NUMBER: 1226 (64-14102)
PILOT: Erhart		PLACE: Arlington

CREW	FLIGHT NO.	GROUND RUN NO.
	228 2-16-68	

WEATHER	PRESSURE ALT.	O.A.T.	WIND
CAVU	340'	10°C	S 4-6 K

PURPOSE: Fluidic Yaw Damper Evaluation

ENG. REPORT NO.	TIME TAKE OFF	TIME LANDING	DURATION
			0.7

C.G.	FROM STA. O.	G.W.	TOTAL FLIGHT TIME TO DATE	TOTAL ENGINE TIME TO DATE
Fwd	126.4	8447 LBS.	381.1	

CHANGES SINCE LAST FLIGHT

A: 1. Daily inspection completed.

This flight was made to evaluate and take data on the yaw dampening. Various pedal step inputs were put in at hover, 60 Knots, 90 Knots and 110 Knots.

The [illegible] dampener greatly increases yaw stability and is a great [illegible] maintaining an exact heading such as would be desired on a g[illegible]ng run. However, the present system has no pilot control l[illegible] the ship is very unresponsive in yaw. In a hover, the slow response to pedal is particularly noticeable and greatly limits the pilot's authority over the aircraft.

86:RGE:bt-10808

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13. ABSTRACT

Flight tests were conducted to evaluate the performance and feasibility of a fluidic yaw damper system that was fabricated by Honeywell, Inc. A standard UH-1C helicopter was used as a test vehicle.

Tests encompassed 8.5 flight hours and 2.9 hours of ground and hangar tests. Operation of the system was normal at all times, and a significant increase in yaw damping was measured. None of the tests revealed any factors that might limit the application of fluidic systems in a helicopter environment. The performance and reliability of the "feasibility" package were much better than expected and helped to create a favorable impression of the concept. Pilot acceptance of the system was good, considering that only simple rate damping was provided without the benefit of pilot loops, quickening, and other sophisticated features of current electronic Stability and Control Augmentation Systems (SCAS). If fluidic stabilization systems were to be incorporated into a production helicopter, these additional features would have to be present to obtain pilot ratings equivalent to those generated by electronic SCAS.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Flight Test						
Fluidics						
Fluidic aw Damper						
UH-1C Helicopter						
Ground Tests						
Hangar Tests						
Fluidic Stabilization Systems						
Stability and Control Augmentation Systems (SCAS)						

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